Rainforest Connection
Tembé Project: Impact Assessment

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Executive Summary

This report summarizes the findings of a feasibility assessment of the USAID-supported research and technology project, "Indigenous Forest Protection Using Remote Sensing Platforms". This project was implemented by Rainforest Connection (RFCx) through a Grant Agreement from the United States Agency for International Development (USAID) Development Innovation Ventures (DIV). The original grant of USD $600,000 for the 2017-2020 period of performance was extended for one-year until July 2021 due to an unavoidable change in the scope of work. This assessment aims to measure the impact of the project in Brazil over the terms of the grant agreement as well as the cost effectiveness of the Guardian technology.

RFCx, in accordance with grant requirements, has requested a systematic, independent and objective third-party review of its USAID-sponsored project in Para, Brazil. The assessment examines the effectiveness and efficacy of RFCx' newly developed satellite-connected Guardians on Brazil's ecosystem protection; tests the assumptions on sustaining the theory of change, assesses the technology as a solution for forest protection in the Tembé, and gathers lessons learned to inform recommendations for improvements.

The Tembé Indigenous People, a tribe based in the rainforest of northern Brazil, have been under constant threat from widespread and large-scale illegal loggers, poachers and drug traffickers. It was physically impossible for the Tembé to protect and patrol their land using traditional methods of patrol. Since 2015, alongside their partnership with RFCx, the Tembé have retaken nearly 15% of their total land area, previously occupied and controlled by illegal loggers and settlers. Now, as the dispute over occupied land escalates, the RFCx system has become a critical part of the Tembé ranger toolkit, utilized to protect the Tembé's land from illegal logging that contributes to widespread deforestation.

This report provides the background of RFCx and their latest satellite Guardian technology, the problem this technology is attempting to address specifically in the Tembé region, a 300-square kilometer area, and then outlines the cost structure in order to determine efficiency and feasibility.
The project has made considerable progress in achieving the planned project outputs and this can be attributed to the progress made on the technology, the strong partnership developed with the local community, and the more efficient patrols to reduce illegal logging activity. This review concludes with recommendations that will serve to further strengthen this project should additional funding become available.

Background

Rainforest Connection (RFCx) is a non-profit organization that believes that a focus on stopping illegal logging can act as an effective barrier to wholesale deforestation and such a focus is likely the cheapest way to fight against global warming and biodiversity loss. The RFCx monitoring system gives its partners the opportunity to protect key rainforest areas and respond to real-time alerts, while sharing large amounts of ecosystem data that help negotiate increased protections in these areas. In some cases, protecting the perimeter of a rainforest can actually mean protecting everything behind it – saving rainforests is the key to saving our planet.

Since 2012, RFCx has developed and deployed eco-acoustic technology, creating the first scalable, real-time acoustic monitoring system, active in 38 countries across 6 continents, with real-time monitoring stations established in 14 countries; ultimately seeking to develop a global acoustic network to halt illegal logging, poaching, mining, and monitoring biodiversity. RFCx is dedicated to

placing conservation technologies into the hands of committed partners on-the-ground to help combat illegal logging.

RFCx was awarded $600,000 of seed funding by USAID DIV for their project in the Northern region of the Brazilian Amazon where the Tembé tribe are based in the State of Pará. RFCx technology platform aims to prevent the encroachment onto the Tembé land for the motive of illegal logging. Deforestation of the Amazon Rainforest in Brazil has surged to its highest level since 2008, between 2019-2020 there was a 9.5% increase from the previous year.

RFCx has developed technology that can detect the specific frequency made by chainsaws and other noises and sends alerts to rangers' mobile phones. This enables the rangers to safely locate illegal logging activity through the Guardian—RFCx in-house developed technology. The Guardian originally began as a technology made from recycled mobile phones that detected and transmitted alerts based on the collection of audio recorded. Due to many limitations ranging from cost to internet connection and network availability, the Guardian now includes customized components designed for the use of low orbit satellites to transmit selectively consolidated metadata and to deliver alerts. This allows the technology to be effective in areas with no GSM network connectivity, which were previously beyond reach of the system. The latest deployed Satellite Guardians were designed, programmed, and implemented in the field over the past 4 months.

In March 2021, RFCx implemented a field test of 30 newly developed infrastructure-independent Guardians. Currently, these Guardians are connected through Iridium Satellites, with the goal to upgrade to Swarm Satellites as the data would be about thirty-five times cheaper than with Iridium and has the capacity to send data messages as well as small soundbites of audio. Swarm will also allow for adjustments to the AI audio models to update the detection algorithm for improved analyses. The technology is consistently improving from its predecessor. We are assessing the latest 30 infrastructure independent satellite Guardians that were deployed in March 2021, **Figure 1.1** below shows a map of the Guardian alert activity geographically in the Tembé area. It will be important to assess the impact in the field in the longer term to fully understand any strengths and deficiencies.

RFCx is working closely with the Tembé to train the rangers for patrol planning to better monitor illegal logging activity with Guardian alerts coming into a centralized location to the rangers. Historically, the Tembé have attempted to negotiate with the loggers on-site and within their territory, but these negotiations have not served as a deterrence, especially when the Tembé previously were unable to determine the location of the illegal logging activity.

The latest Satellite Guardian technology was developed using an AI model that detects the acoustic patterns of chainsaws and sends clustered reports of activity to the cloud and then directly to the rangers' mobile phones through an online platform or dashboard. These alerts are saved in the Cloud, further analyzed to inform patrol planning to prevent illegal logging and deforestation. While previous iterations of the Guardian technology have sent alerts immediately upon noise detection, RFCx opted to utilize clustered alerts (grouped together), designed to fit the rangers' needs. Alerts are amassed over a customizable period of three hours and the areas with the most alerts are sent to the Cloud to be analyzed by artificial intelligence (AI) and human intelligence. It is designed and configured to the rangers' needs by identifying hot zone areas of activity. The vast, remote terrain proves difficult for rangers to respond in real time (immediately).

The Tembé tribe live on 300 square kilometers of land in the State of Para. They have been facing issues not only of deforestation from illegal logging, but also fires and cattle farming as a direct result of encroachers onto their territory. In addition to biodiversity loss and habitat destruction for critical species, the Tembé have also been fighting issues of drug growers, drug trafficking and poaching. Since 2015, RFCx has been working directly with the Tembé to address the largest and most costly issue they are facing: large scale illegal logging. Prior to their connection with RFCx, the Tembé took it upon themselves to patrol the forests by surveying the land for loggers who, more often than not, are armed to protect their camps. This has become increasingly dangerous as Tembé youth have joined the patrols as well. Not only do the Tembé face security threats from the illegal loggers, but also surveying the vast terrain of the rainforest is dangerous and resource intensive. RFCx's technology now alerts rangers of chainsaw activity to ensure their patrols are more effective and efficient in current and future logging events.

Large scale deforestation contributes to 17% of all carbon emissions globally, leading to species extinction, causing droughts, affecting upwards of twenty million people, totaling from 2-5 trillion USD in economic loss annually. According to the Global Forest Watch, from 2000 to 2020 Brazil has lost a total of 12% of total forest coverage. When looking at the State of Pará and the region occupied by the Tembé tribe, during the same period, there was a 14% loss of forest, generating 9.08Gt of CO2 emissions. This has led to net emissions as opposed to net removals of CO2 in the atmosphere with a net influx of carbon dioxide in the amount of 172Mt each year. Not only is illegal logging and deforestation directly contributing to global warming and climate change, but there is risk of extinction to critically endangered species in this biodiversity hotspot. The IUCN Red List notes that logging and wood harvesting is the second largest contributor to species endangerment and extinction in Brazil.

In addition to the damaging effects from global warming and the disruption of ecosystems, the forest plays a crucial role in everyday life for the Tembé tribe. Not only does it nourish the Tembé with critical natural resources and food supply, but it also plays a role historically and culturally. Illegal logging is disrupting food sources of both plant and animal, forest coverage and trees that could be utilized for shelters, tools, transportation, and the culture that the Tembé tribe have celebrated for generations. Protecting the Tembé land from illegal logging makes cultural, economic, social, and security sense in addition to the environmental impact for future generations.

Former and current methods of addressing deforestation have included community-based forest management as well as more primitive tracking technology such as using a spray directly on the trees to other log tracking devices and accountability applications. There is technology platforms that track the logs once they've been harvested (illegally or not), but these technologies, such as StarDust and TreeTag allow for monitoring and managing of data, but they do not capture real time events, and only after the trees have been illegally logged, so the rangers serve in a reactionary role.

The Guardian paired with community-based forest management training of Tembé rangers allow for a quicker and more proactive response even in remote, hard to access areas. Chainsaws are one major tool used for clearing out forested area, and even if detected after the trees are cut, it still serves as a detection alert early enough for rangers to respond. Large scale logging takes many weeks if not months of planning and successful execution so there is still an opportunity to intersect and dismantle the operation if the rangers plan and prepare well. Even in rare instances that the rangers cannot immediately access an area with high levels of chainsaw activity as detected by the Guardians, the technology still serves as a proactive deterrent for large scale logging operations.

A strategic decision was made with the Satellite Guardians to have clustered reports instead of individualized immediate alerts. The technology has improved so that there are very few false positive alerts created by the devices. Also, it cannot be underestimated that when the rangers get to an area after any illegal logging activity has started, their presence and response has the ability to deter future encroachers or repeat offenders.

"Acoustic sensing is an emergent cost-effective technology with game-changing potential to expand the scope of biodiversity monitoring. With the recent developments in acoustic monitoring technology, we are now able to do what was previously inconceivable with traditional-ground based methods." – RFCx Topher White

Review Methodology & Data

RFCx contracted JG Global Advisory (JGGA) to conduct a third-party impact assessment. JGGA is a globally recognized project management consulting firm that specializes in law enforcement, international security, and environmental issues. In addition, JGGA conducts third party, in-depth assessments to ensure projects are being implemented as aligned with the statement-of-work, on schedule and within budget, and effectively implemented for a sustainable impact; creating monitoring and evaluation mechanisms to improve project deliverables and enhance outreach.

The JGGA team developed a questionnaire (see **Appendix IV**) to address the RFCx primary research questions from the Terms of Reference (ToR) around cost effectiveness and ecosystem protection and governance.

Phone Interviews. The JGGA team conducted a series of semi-formal interviews to the dispersed RFCx team located in the U.S., Brazil, and the United Arab Emirates. Based on the questionnaire developed, the team was able to collect qualitative and quantitative data on the cell-phone-based Guardian technology, the new Satellite Guardian technology, and general history and understanding of the expenses to develop a proper cost-effectiveness analysis. A complete list of interviews conducted is included in **Appendix II**.

Document and Desk Review. We collated and collected key RFCx documents and recordings that include updates, patrol reports, milestone progress reports, summaries of activities and daily duties provided by the RFCx staff. JGGA team reviewed technical documentation and conducted desk research on open-source networks. A complete list of documents reviewed is included in **Appendix III**.

Monetizing Deforestation. Due to the recent deployment of the Satellite Guardian (March 2021), there is not a significant amount of quantitative data on total forest recovered and thus the monetary gains from deterring illegal logging in the Tembé region. This will be outlined further in the limitations section, however this led the team to require open source research monetizing

forests in other areas in order to better explain and contextualize the cost-effectiveness of the technology.

Cost Structure. In addition to collecting cost information through phone interviews, the team developed a table to outline the cost structure since the beginning of the project in 2017. JGGA put together a list of funding received along with the itemized list of costs expended. This document was then shared with the RFCx team to validate and confirm more precise costs, such as training, and R&D. JGGA used an example of a traditional protection strategy project funded by the U.S. government in Brazil as a comparison.

RFCx Dashboard. JGGA was also given access to the RFCx Web Dashboard that collects and tracks the data being reported from the active Guardians in the field. The Dashboard has allowed the team to navigate, organize, and submit patrol reports through visualization of the clustered alerts from each active Guardian in their respective location. The Dashboard outlines in various charts and graphs the level of chainsaw activity, and other key information such as how often over time, for how long during each alert, and in which locations. The Dashboard is most helpful to the rangers who analyze this data to set up patrols based on the most active chainsaw sites. As of early June 2021, 155 chainsaw alerts have been generated from the deployed Satellite Guardians, see **Figure 1.2** below.

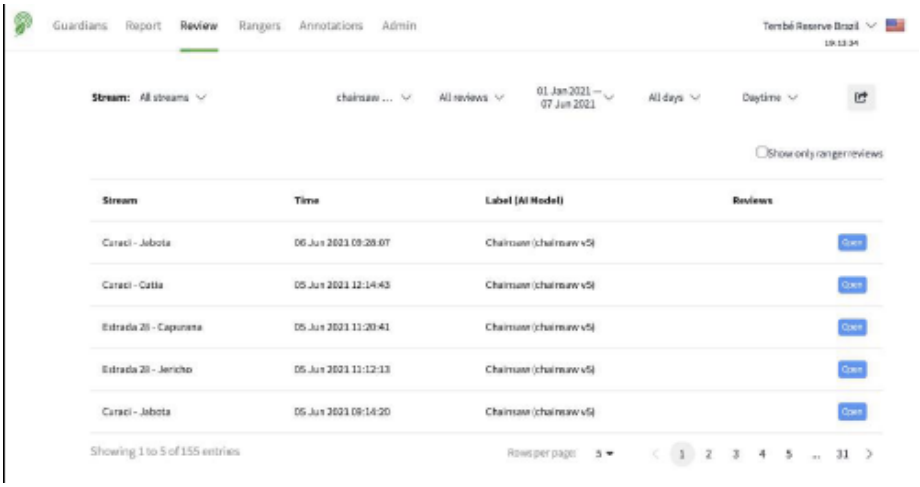

Fig. 1.2 Dashboard Chainsaw Alerts from the Guardians

Limitations to the Evaluation

A major limitation to the assessment was the inability to conduct a site visit due to the COVID-19 pandemic. In addition, the timing of the survey coincided with the rainy season which limits signal and access to the rangers in the field. Because this is not typically a peak season for loggers, chainsaw alerts are likely less "active" than during dryer months and anticipated increased logging.

JGGA was able to successfully conduct an interview over the phone with the Head Ranger. Originally, **interviews with additional members of the Tembé tribe were planned,** but unsuccessful due to limited signal and the rangers being out on operational patrols.

Another significant limitation is that RFCx **collected far more qualitative data**. In order to measure progress, we would need a longer period of assessing the most advanced version of the

technology and more quantitative data to support the theory of change. Additionally, there was **no baseline available** for key data points, such as the number of illegal loggers, number of illegal loggers disbanded, number of repeat offenders within the territory, to be able to measure progress and full impact of the technology used.

The latest technology for the satellite Guardians was recently deployed (March 2021) only a few months prior to the commencement of this assessment (May-July 2021). The long-term impact will be more-easily measured against a baseline during the peak logging season. In order to better understand the effectiveness of the Guardian technology and patrols, this report will be utilizing data from comparable technologies acknowledging, a) there are clear distinguishing characteristics between the Guardian and other anti-logging technologies, and b) the Guardian technology is more proactive as opposed to reactive. **There are limited exact comparisons to the Satellite Guardian technology to compare exact cost structure.**

RFCx was extremely helpful and accommodating in briefing the consultant and providing all requested documentation for follow-up meetings and correspondence.

Project Review Results & Summary

RFCx has designed an innovative solution to address illegal logging and settler encroachment on the Tembé land. Prior to the RFCx project, approximately 30% of the Tembé land was occupied by illegal loggers and settlers. The Guardians have empowered and motivated the Tembé to increase the number of patrols in a strategic way to areas where there is increased activity/chainsaw noises, and thus far has deterred illegal loggers by destroying their equipment, which has been found as a major deterrent for future criminal activity.

RFCx has earned the trust and respect of the Tembé tribe, leading to a collaborative relationship that results in open communication and coordination for project success. The Guardians have also minimized exposure to surprise encounters with criminals; thereby increasing the safety of the rangers. Early indications show that ***illegal logging in this region has decreased*** due to the close collaboration of RFCx with the Tembé rangers and increased patrols**;** measuring how much logging activity has decreased will need to be addressed when baseline data is captured.

The Guardian is a ***low cost, low maintenance technology*** that is constantly evolving. Through the collaborative relationship and feedback between the Tembé and RFCx, there have been consistent updates to the Guardian, overcoming various limitations, including connectivity and data storage. RFCx resolved the challenge of data retrieval from the SD card on the devices located in the treetops with the creation of the Edge Devices. The Edge Devices are being used in parallel with the Guardians for biodiversity monitoring and located at the base of the trees (compared to the treetops). The Tembé rangers have been trained in data retrieval from the Edge Devices. The chainsaw frequencies are sent to the Cloud, but any data retrieval at the moment is only required for biodiversity monitoring purposes as opposed to being necessary for threat detection, custom designed for the Tembé to utilize for other purposes outside of detecting illegal logging activity.

The social costs can be seen at both the micro and macro levels: the global effect deforestation has on the Amazon, and the local impact to the Tembé tribe. According to the NRDC, illegal logging in Brazil is the top country for deforestation emissions which accounts for 25% of the world's total deforestation emissions of carbon dioxide. American Forests estimates that if deforestation is reduced by half over the next fifteen years, then this would save 3.7 trillion USD in climate change related costs globally.

From 2002 to 2020, Global Forest Watch recorded a total loss of 64.7Mha of deforestation. The State of Para makes up approximately 9.22Mha or about 14% of the total loss of deforestation. By this logic, cutting deforestation in half in this area alone, could contribute to saving **518 billion USD** in climate change related costs, which includes social costs.

When addressing the social and economic costs to the Tembé directly, there are a range of losses from resources to income-generating activities to cultural heritage. The Head Ranger discussed the economic impact that the Tembé are facing from illegal logging. The Tembé use the forest for their supplies and food source. Two of the larger income-generating resources from the forest include açai berries and andiroba from the trees for the community. They collect as much of these two fruits as possible to sell at markets weekly. The income generated from selling these fruits is around 200 USD per month, a significant source of income for the tribe. If the loggers are destroying the trees that bear these fruits, then the Tembé are not only losing vitamin-rich food sources, but they are also being robbed of the opportunity to make 200 USD monthly in the local markets. Not only are these fruit bearing trees at risk when encroachers enter the Tembé land, but other vital ground-growing plants are wiped out that the Tembé use for medicinal purposes, and without these they are not able to heal their community from illness. This can translate to illnesses and injuries becoming fatal or chronic when left untreated, forcing members of the tribe to find other ways to treat these ailments. Additionally, COVID-19 and the problem of zoonotic diseases are becoming more prevalent as loss of habitat from deforestation forces wildlife closer toward communities. The pandemic has hit Brazil hard and serves as a strong reminder of the health security risk that can be costly to any society.

In addition to the destruction of critical forest coverage that serves as carbon capture and storage to reduce global warming, these illegal logging activities are harming the animals that depend on the forests as their habitat. The Tembé hunt a variety of game including: peccaries, agouti, paca, monkeys, armadillos, tapir, tortoises, game birds and deer in the Amazon as an important food source. When habitat loss increases by large-scale logging activities, the Tembé also lose essential food sources. Food has always been a centerpiece for every culture, and the Tembé are not only losing their food source, but their cultural heritage. The Head Ranger explained that future generations, including the current children of the tribe may never see certain plants or animals, and that this will rob the tribe of their history. The Guardians not only reduce illegal logging and forest loss, but also reverse irreparable damage before the tribe loses their income, food sources and cultural heritage.

Cost Effectiveness:

Does RFCx offer a more cost-effective solution than traditional protection strategies?

Yes, when comparing a traditional anti-poaching project in Brazil for $1M over a two-year period that aids to protect ecosystems, stem poaching and illegal logging, and enhance ranger capacity to investigate and protect areas, this project is much more cost effective and proactive in the prevention of illegal logging and forest protection. Additionally, the amount of time and money to conduct short, 1-3 day trainings for approximately 40 rangers is very economical. The customized or tailored Guardian deployed in large, remote areas of the Tembé land makes this a very cost-effective solution.

Ecosystem Protection and Governance:

Does this Guardian technology actually work as intended?

The Guardian was intended to protect indigenous forests using remote sensing platforms. The 30 Guardians that have been deployed throughout the Tembé area have contributed to this goal with its chainsaw alerts triggering increased and targeted patrols, leading to the disruption of illegal logging. This technology provides around the clock, 365 days per year monitoring with near real time alerts sent to the rangers with critical information needed to plan effectively, and conduct strategically targeted patrols and operations, including minimizing ambush risk to the rangers.

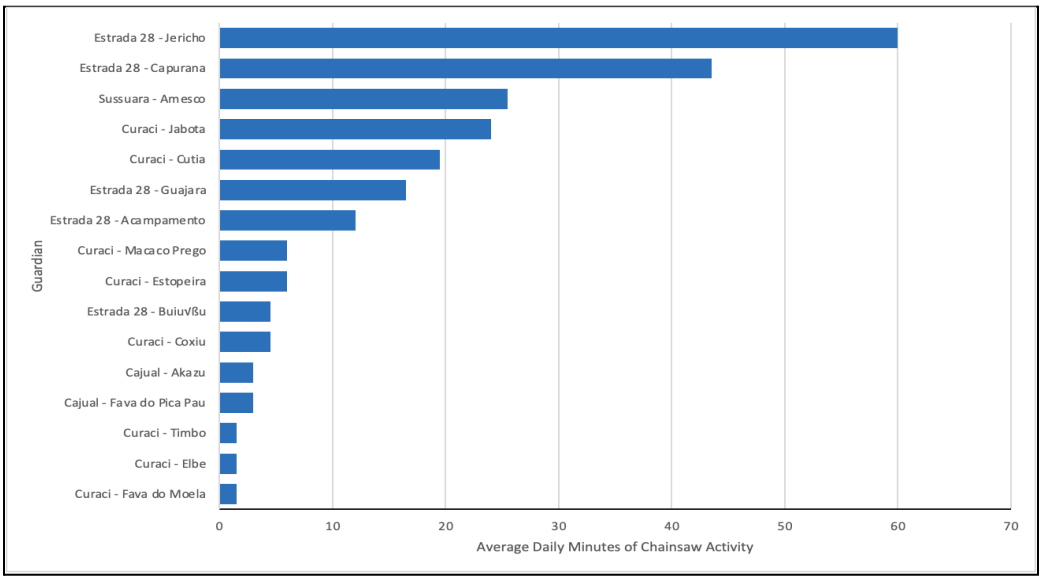

Fig. 1.3 Average Daily Minutes of Chainsaw Activity for Each Guardian

Through continued enhancement to the platform, Guardian technology has matured substantially, from what was originally recycled mobile smart phones with attached solar panels and limited connectivity to now Satellite mini-computer systems with reliable alerts and capability for storing large files of data. In addition, the RFCx AI Hub has new added functionality of heat maps that plot the alerts generated by the Guardian, making it simple and easy to immediately spot areas of high activity for patrol planning.

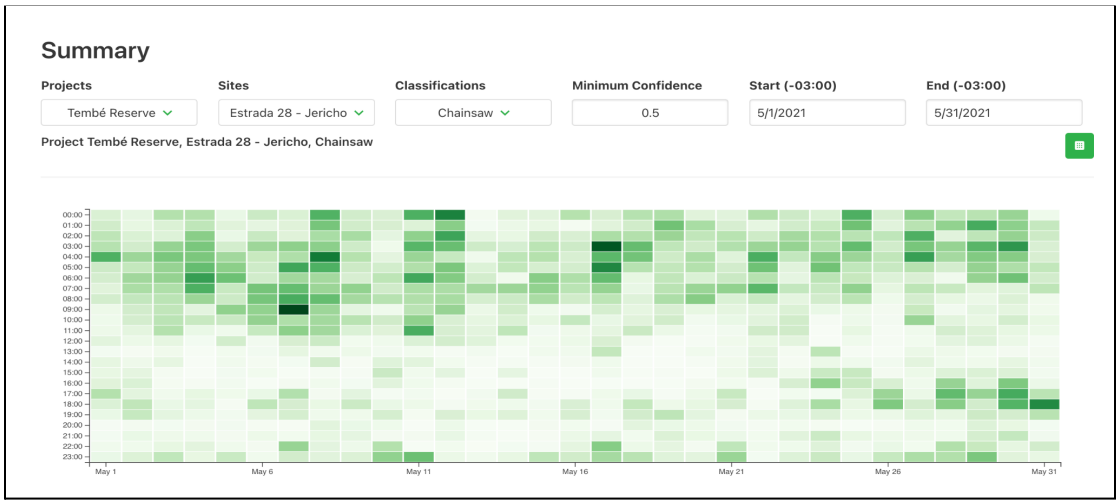

Fig. 1.4 Heat Map of Chainsaw Activity Intensity near Guardian E28

The most recently enhanced Satellite Guardian is now independent of infrastructure, enabling full mobility across remote forests of Para.

Guardian has also proven to be resilient against natural elements, such as wind and rainstorms. Of the 30 Guardians deployed in the region, less than 6% have been decommissioned due to natural elements.

Does it lead to ecosystem protection?
Preliminary evidence indicates Guardian has been an effective deterrent to illegal logging. Using data alerts from the Guardian, more frequent and efficient patrols now intercept hot zones areas, apprehend illegal loggers, and confiscate their equipment. The efficacy of the joined efforts of technology and the patrol team also deters illegal loggers from returning to these spots. This impact will be more-easily measured against a baseline during the peak logging season.

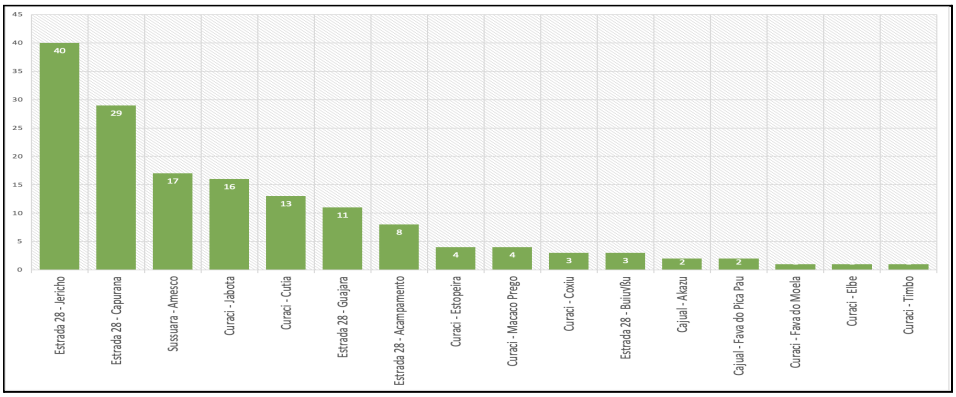

Fig. 1.5 Breakdown of Alerts per Guardian

Are the outputs from the monitoring system reliable?
Over the last three years, the amount of data stored to date is 1.8 million hours (as of June 2021), an increase in RFCx application users year on year for both incident reporting and alert management as well as sharing with project beneficiaries. The number of ranger responses based on the reports filed in the Dashboard have increased each quarter when comparing the previous year. The number of ranger interventions have also increased in the last year and large-scale interventions that engaged law enforcement authorities has also increased in the last year. The number of planned interventions is on an increasing trend.

Regarding system accuracy and what is being captured to date, the number of false positives from the alerts has dropped from 52% in 2019 to .337% in 2020. The team is unable to calculate the number of false negatives at this time. Therefore, the Guardian is continually improving and the outputs from the monitoring system are now very reliable.

Does it increase awareness of threats caused due to illegal logging?
Guardian most definitely has increased awareness of threats due to illegal logging. The Tembé rangers were previously conducting less than 2 patrols a year within their territory, but now the patrols are much better organized and strategically planned 2-3 times per month (since Spring 2021).

The alerts are received in batches, centralized, and sent to the rangers who can better prioritize where the most chainsaw activity is located across the 30 locations within their territory. Additionally, the rangers have a better understanding of the data through the AR2 unit and now have a more efficient and effective structuring of their patrols.

There has been an increase in the number of incidents of illegal activity captured by the system from 129 reports were submitted with 26 reports qualified by the RFCx team as verified incidents in 2019 to 619 reports submitted and 34 reports qualified as verified incidents in 2020. In 2021, 44 reports were submitted where 18 were qualified as verified incidents. This may be explained as more strategic reporting, more accurate reporting, and better awareness of streamlined activity.

Does it allow for an increase in collaboration based on data shared with different stakeholders?
Guardian has absolutely facilitated increased collaboration based on data shared among different stakeholders. The data provided by the Guardians empowers the Tembé with the necessary information to garner interest and critical support from Federal Police, Ministry of Environment and Sustainability, the Public Ministry, SEMAS and other indigenous organizations.

RFCx has also increased their partnerships and business interests with corporations and other NGOs, academic institutions and biodiversity scientists who are collaborating with RFCx for biodiversity monitoring.

It is also worth noting that RFCx has fully earned the trust of the Tembé, and this credibility is key to continued collaboration and project success should the RFCx seek to expand the program.

KEY PARTNERS	INDIGENOUS ASSOCIATIONS
Ministério Público Federal em Paragominas Federal Public Ministry at Paragominas - Public Prosecutor, Mr. Milton Tiago Araújo de Souza Júnior.	**Agitasi - ASSOCIAÇÃO DO GRUPO INDÍGENA TEMBÉ DAS ALDEIAS SEDEE ITUAÇU** ASSOCIATION OF THE TEMBÉ INDIGENOUS GROUP OF THE SEDE AND ITUAÇU VILLAGES President: Antonio Sarmentos dos Santos
SEMAS - Secretaria de Estado de Meio Ambiente e Sustentabilidade State Secretariat for the Environment & Sustainability Cabinet of Mr Mauro O' de Almeida, Secretary.	**Villas-Bôas Foundation** Mr Paulo Celso Villas-Bôas, lawyer
DPC - Diretoria de Planejamento Estratégico e Projetos Corporativos Board of Strategic Planning and Corporate Projects Coordinator: Mr Wendell de Andrade	Chief Sérgio Tembé (Tekohaw Village)

CIMAM (Centro Integrado de Monitoramento) Integrated Monitoring Center Coordinator: Mrs Jakeline Viana	Chief Naldo Tembé (Sede Village)

Fig. 1.6. List of Key Stakeholders

Does the monitoring technically work as expected in the field?
As the Guardians technology continues to be refined, monitoring is now enhanced through combined Artificial Intelligence (AI) and human intelligence – the Alert Review & Response (AR2) Unit. The RFCx team set up a dedicated unit to support the Tembé rangers in April 2021. The AR2 unit realized the ranger reports were critical to connecting the alert generated to direct response from the Rangers; however, there became a need for a clearer process to ensure no missed information is by the team for on the ground observations, insights and in the field reporting. This unit reviews the ranger reports, translates it, linking it to the cluster of alerts, which forms the basis of the ranger patrols. The combined effect of AI-AR2 provides for a more comprehensive understanding of reality on the ground.

Guardian still has untapped potential in capturing additional sound indicators to illegal logging activity. For example, the Dashboard has the platform to capture other sound or noises (i.e., vehicles) that can be enabled in the future should resources become available.

Can the recordings from the Guardians be used for biodiversity monitoring?
Yes. The latest version of Guardian installation was coupled with the deployment of 40 RFCx Edge Devices to collect data for biodiversity monitoring in March 2021, but the team has been structing biodiversity monitoring projects for the past year. In order to acquire the recordings, the Tembé have been trained to retrieve the biodiversity data from the Edge Devices located at the base of the same trees where the Guardians are located. For this reason, RFCx opted to create a program for biodiversity data collection at a larger scale using inexpensive devices in conjunction with Guardian deployment.

Over a period of three weeks, the devices acquired over 230,000 recordings from 39 sites covering different habitats. In the first screening of the recordings, 167 species were identified. This is a promising by-product of the initial application of the Guardian and one that can be useful for many different purposes in both conservation science, criminology and other academic fields.

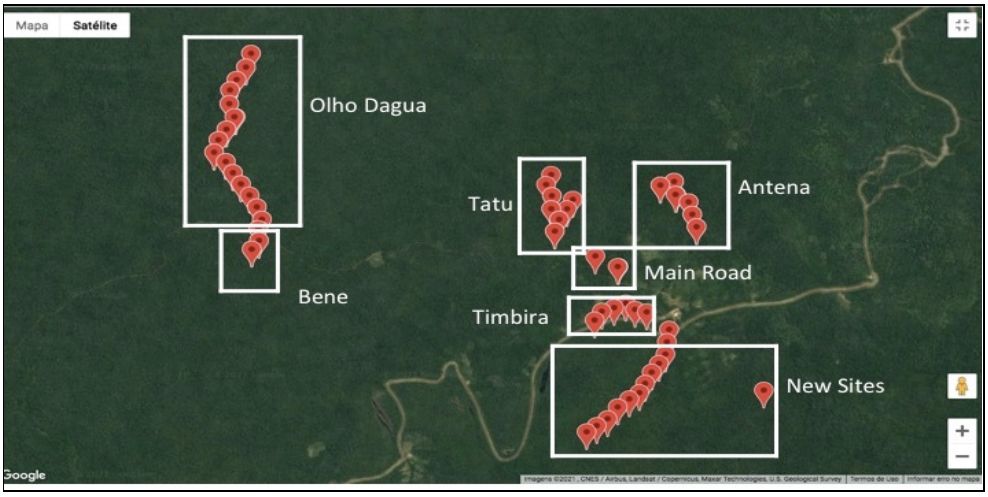

Fig. 1.7 Map of Deployment of Edge Devices

Does it open up new avenues of revenue through biodiversity monitoring?
Yes, the Guardian platform can be marketed to open new avenues of revenue through biodiversity monitoring. Engaging the private sector, in particular major suppliers of wood and timber products may see this as an opportunity for clean and transparent supply chains under the corporate social responsibility agenda. Academic institutions who are engaging in research on music and acoustics or conservation science could see this as a useful tool in their toolbox to equip them with knowledge of unidentified species. Additionally, this is also a good opportunity for companies seeking to access carbon credit markets to reduce their carbon footprint in GHG emission reductions.

Findings, Conclusions, & Recommendations

The project is well designed and has effectively engaged the local community on implementing results-oriented technology and crime prevention for the rangers in order to effectively reduce deforestation, enhance transparency and stem illegal logging that has the potential to lead to significant long-term benefits, including contributing to the reduction of climate change. The project has made considerable progress in achieving the planned project outputs and this can be attributed to the progress made on the technology, the strong partnership developed with the local community, and the more efficient patrols to reduce illegal logging activity.

In terms of addressing deforestation, the project has excelled in developing local NGO partnerships that have been instrumental in implementing strategic ranger patrols, reduction in encroachment by nearby tribes, illegal logging and biodiversity monitoring. The project has also achieved high levels of success in assisting local forest communities and building trust and a strong working relationship with the Tembé. The following recommendations were developed to ensure the project concludes in achieving full success and unlocks opportunities for continued and new partnerships.

Quantify Impact. Develop processes for capturing baseline data and managing that data in the short and long-term in order to measure progress. Examples of data that should be captured: number of people apprehended, the number of illegal logging networks dismantled, rate of deforestation, CO2 emissions reduced, number of repeat offenders illegally logging, number of incidents that elicit a response from the police. This will assist with overcoming the lack of quantitative data to better capture progress and impact for future assessments. However, the existing data sets to date can provide insightful trends and updates on modus operandi of illegal

loggers in the region and should continue to be captured and closely monitored, utilizing this information and translating it to potential donors for funding opportunities.

Project Sustainability. Technology on its own is not the game changer, but rather the human element coupled with agile technology is the game changer. The strong relationship with the Tembé has not only motivated them to take back control of their land and protect it, but also the mutual respect and strong communication between RFCx and the Tembé has been critical for the project's long-term success. Local buy-in has been key to the success of the Tembé project for the RFCx.

Innovative Partnerships. Garner innovative partnerships to ensure the continued success of the program beyond Pará. The unintended by-product of the Guardians is the ability for biodiversity monitoring which will open up new avenues of funding opportunities. Engage additional stakeholders in the conservation, science, and academic fields, including international organizations such as UN REDD+, GEF, and World Bank. At the local level, an improved and proactive relationship with the state and federal law enforcement agencies will be critical to maintaining their land and eradicating illegal logging activity.

Project Scalability. In order to scale at a much greater pace, leverage RFCx products/technology with existing efforts by large companies who provide solutions, such as through Command, Control, Communications, Computers Intelligence, Surveillance and Reconnaissance (C4ISR). Advanced C4ISR capabilities provide an advantage through situational awareness, knowledge of the adversary and environment, and reduced time between sensing and response. These companies have resources, (hundreds of millions of dollars each year). They often manage a central command center for data analysis and response teams that could be complementary to the RFCx projects working globally.

Appendix I: Project Timeline

Objective	Task	POC	Dates
Gather relevant data, information, and reporting	Document review	JGGA	May 17-24, 2021
	Identification of comparable alternatives	JGGA	May 17-24, 2021
Interview RFCx stakeholders and on-the-ground personnel	Questionnaire development	JGGA	May 28, 2021
	Conduct interviews	JGGA	May 27-Jun 3, 2021
Compare RFCx method to alternatives in financial and method effectiveness	Conduct cost effectiveness analysis	SM	Jul 12-14, 2021
Provide a draft final impact assessment report for RFCx review and feedback	Synthesize document review, alternative methods, interviews, and cost-effectiveness analysis	JGGA	Jul 14, 2021
Project debrief and discussion of draft review	Conduct teleconference to discuss draft review.	JGGA/RFCx	Jul 21, 2021
Complete all objectives within agreed timeline for the use of RFCx and its financial investors	Submit final report to Rainforest Connection	JGGA	Jul 26, 2021

Appendix II: List of Interviews

Type	Name	Title	Method/Location
Internal	Topher White	RFCx CEO	Video Conference
Internal	Bourhan Yassin	RFCx COO	Conference Call
Internal	Mahreen Qazi	RFCx VP	Video Conference
Internal	Pedro Rosa	RFCx Local	Video Conference
Internal	Gabriel Leite	RFCx Local	Conference Call
External	Ranger Valdeir	Head Ranger	Conference Call

Appendix III: Catalogue of Documents Reviewed

No.	Document Title	Notes
1	RAINFOREST FE AWARD AID-OAA-F-17-00050	2017
2	RainForestConnection_AID-OAA-F-17-00050_MOD01-Signed	2020, Revised Milestones
3	tembe letter	Informal recommendations/issues
4	Tembé Patrol Letter - RFCx Feb-18-2020 (1)	2020 Recommendations
5	WIP - USAID Milestone 2 Progress Report	circa 2018, Milestone 2
6	USAID_Milestone_2-Progress_Report-16122018	circa 2018, Milestone 2 with RFCx Guardian stats
7	RFCx USAID Progress Report - Milestone 3 - Sep2020 V1	
8	Milestone 4 5 6	
9	USAID Milestone 3 alert calculation	
10	RFCx Kickoff Agenda	
11	RFCx Documents/Questions	
12	RFCx Workplan	
13	RFCx Interview with COO Bourham and CEO Topher	
14	2020 Tembe patrol planning report	
15	2020-UAAI-0002-2	Applied artificial intelligence
16	Pedro Update 1	Audio
17	Pedro Update 2	Audio
18	Philippines Alerts Review 2020	
19	RD-ChainsawDetectionModel-YAMNetReport-300720-2039-8	
20	Relatorio Patrulhas Aldeia Tekohau	In Portuguese
21	Tutorial App RFCx Ranger 2.0	Video--In Portuguese
23	2019-08-05-AGITASI-SEMAS.pdf	
24	2020 Tembé patrol planning report	
25	2020 Tembé patrol planning report.pdf	
26	2020-UAAI-0002-2.pdf	
27	Cheif Sergio Letter - P.jpg	
28	Chief Sergio Letter.pdf	
29	Logging complaint Tembé aug 2020.pdf	
30	Pedro Update 1.ogg	
31	Pedro Update 2.ogg	
32	Philippines Alerts Review 2020.xlsx	
33	RD-ChainsawDetectionModel-YAMNetReport-300720-2039-8.pdf	
34	Relatório Patrulhas Aldeia Tekohau -2019.pdf	
35	SEMAS Letter - ENG (1).pdf	
36	Tembé Patrol Letter - RFCx Feb-18-2020 (1).pdf	
37	Tutorial app RFCx Ranger 2.0.mp4	
38	USAID milestone 3 alert calculation.xlsx	
40	Reviewed Alerts 16122018	

41	Tembe Carbon Project Diligence	
42	Tembe Reserve Project - Key Points 2021	
43	Covid Updates	
44	USAID Milestone 2 Progress Report - V2 Last Updated 16122018	
45	USAID_Milestone_2-Progress_Report-16122018.pdf	
46	WIP - USAID Milestone 2 Progress Report.pdf	
47	RFCx USAID Progress Report - Milestone 3 - Sep2020	
48	RFCx USAID Progress Report - Milestone 3 - Sep2020 V1.pdf	
49	SF-270-Grant-AID-OAA-F-17-00050-Milestone-3-Payment.pdf	
50	Statement of Completion - Milestone 3.pdf	
51	SF-270-Grant-AID-OAA-F-17-00050-Milestone-4-Payment.pdf	
52	Statement of Completion - Milestone 4.pdf	
53	RFCx USAID Progress Report - Milestone 4 - May2021	
54	Impact Assessment Progress Report.pdf	
55	Letters to Institutions	
56	Milestone 5 6	
57	RFCx USAID Progress Report - Milestone 5 - June 2021	
58	Tembe Plan	
59	usaid milestone 5 payment.PNG	
60	SF-270-Grant-AID-OAA-F-17-00050-Milestone-5-Payment.pdf	
61	Statement of Completion - Milestone 5.pdf	
62	Relatório Parceiros RFCx.pdf	
63	Report - 10 Jun 2021.pdf	
64	Stakeholder Report	
65	TEMBÉ INDIGENOUS RESERVE STAKEHOLDER REPORT-1.pdf	
66	Milestone 6	
67	Satellite Guardian Support Letter	
68	Notes_210615_182626 (1).pdf	
69	PATROL 1- EVIDENCE AND RANGER APP FEEDBACK	
70	Tembe Next Step_Coraci river.ogg	Audio
71	WhatsApp Ptt 2021-06-16 at 2.54.50 AM.ogg	Audio
72	WhatsApp Ptt 2021-06-16 at 2.59.09 AM.ogg	Audio
73	WhatsApp Ptt 2021-06-16 at 2.56.01 AM.ogg	Audio
74	Patrol - Estrada 28 June 2021	
75	BIODIVERSITY AS AN INCENTIVE FOR COMMUNITIES TO ACT	
76	RFCx USAID Milestone (revised) Supporting Material July 2020	
77	USAID Meeting Notes and Action Plan	
78	WIP USAID RESPONSE SAVED FIRST DRAFT - JULY 2020	
79	WIP-USAID RESPONSE	
80	RainForestConnection_AID-OAA-F-17-00050_MOD01-Signed (1)	
81	RainForestConnection_AID-OAA-F-17-00050_MOD01-Signed (1).pdf	

82	RFCx USAID Milestone (revised) Supporting Material	
83	RFCx USAID Milestone (revised) Supporting Material.pdf	
84	USAID Milestones 2020-Working Document	
85	USAID revised milestone budget	
86	WIP-USAID Milestones 2020	

Appendix IV: Questionnaire

	Primary Questions
1	Does this Guardian technology actually work as intended?
2	Does it lead to ecosystem protection?
3	Are the outputs from the monitoring system reliable?
4	Does it increase awareness of threats caused due to illegal logging?
5	Does it allow for increase in collaboration based on data shared with different stakeholders?
5	Does it allow for increase in collaboration based on data shared with different stakeholders?
6	Does the monitoring technically work as expected in the field?
7	Can the recordings from the Guardians be used for biodiversity monitoring?
8	Does it open up new avenues of revenue through biodiversity monitoring?
	Technology
1	Do seasonal circumstances change the effectiveness of the Guardian tech?
2	Are there other circumstances that have made its effectiveness variable?
3	How often does the technology have to be serviced ideally? Realistically?
4	Would you say the alerts from the Guardian are accurate (how many "false alarms" do you get)?
5	Are there areas where Guardian tech is needed but cannot be placed for reasons other than terrain or funding? Why is this?
6	How does the Guardian tech hold up against elements of nature?
7	Has the Guardian tech been subject to damage or theft?
8	How do you mitigate the rangers from ignoring an alert from the Guardian tech?
9	What is the Guardian tech's range?
	People
10	Have you seen an increase in collaboration with different stakeholders?
11	Are the rangers checking the illegal loggers outside of their patrols due to the Guardian alerts?
12	How effective are the rangers in stopping illegal loggers when they confront them?
13	Are illegal loggers aware that this technology is being put in place?
14	Does the Tembe rangers have the capability to install and maintain the technology themselves?
15	How high of a risk do you see corruption as playing a factor with the Tembe rangers?
16	How much are rangers paid?
17	How much does it cost (materials, etc) to fully train a ranger?
18	How much time does it take to fully train a ranger?
19	What do illegal loggers do when they are confronted by the Tembe rangers for the first time?
	Goals
20	Has the Guardian tech decreased illegal logging?
21	Has the Guardian tech decreased the chances of illegal loggers returning?
22	Do you see the Guardian technology as a long term solution? If not, what does a long term solution look like?